Original article

The relationship between dietary habits of late adolescent individuals and the heavy metal accumulation in hair

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Abstract *Study Objectives:* This study aimed to determine the effects of smoking status and dietary habits on heavy metal accumulation in late adolescent students studying at Sinop University. *Methods:* This experimental research was conducted between 09 October and 15 November 2019. The population of the study was composed of 18-21 age (late adolescent period) students studying at Sinop University, School of Health. In the determination of the research sample, the selection of students who accepted to participate in the research as the case selection criteria, who did not have any mental or chronic disease/syndrome, and who did not use drugs continuously was taken into consideration. For the collection of research data, an information form about the weekly consumption of foods and smoking status was prepared by the researchers considering the geographical and physical locations where the students are located. After collecting the forms filled by students, 0.5 g hair samples were taken from volunteered 41 students to analyze the concentration of heavy metal in the hair and analyzed in the ICP-MS device. The data were evaluated using the Mann-Whitney U test in the SPSS (version 22.0) statistical program. *Results:* As a result of this research, it has been revealed that there was a statistically significant relationship between some food groups (lettuce, chips, instant soup, salami, and trout) that students express at least once a week and the heavy metal concentration detected in their hair. *Conclusion:* It was revealed that there is a relationship between individuals' dietary habits and heavy metals in late adolescence.

Keywords: Heavy metal, Adolescent, Smoking, Hair

Introduction

The effects of environmental pollution on human health can be analyzed with some biological materials such as teeth, hair, and nails, and it is possible to monitor changes in the body. Hair and nails are biomaterials in the structure of fibrous protein consisting of keratin (1,2), a long-term with many trace elements accumulating in the hair that can provide data for a long time in determining the health status of an individual's body hair. (3,4). On the other hand, the concentration of these elements can be used to investigate dietary exposure to chemical pollutants, especially toxic metals, including the effects of smoking and drug use of an individual or population (5). For this reason, hair and nails are considered as valuable tissues for studies to monitor the exposure of individuals to environmental pollution. The International Atomic Energy Agency (IAEA) also accepts the use of mineral analysis of hair to measure the levels of essential and toxic trace elements in living organisms, including humans (6,7).

Elements are naturally occurring chemical compounds and can be found in various concentrations in the environment. However, industrial, domestic, agricultural, etc. applications affect not only water, air, and soil, but also crops and animals and cause these elements to rise above their natural levels in the environment. Therefore, the food chain is one of the most important ways of exposure to metals (8,9). These metal concentrations in foodstuffs can also pose various health risks on populations associated with the food chain.

Heavy metal concentration in the body is an important indexing parameter in the determination of toxicity and assessment of its severity (10). Nail and hair growth in humans are life-long processes and provides a longer integration period for heavy metals. Its roots are heavily influenced by the state of cells and human hair and nails provide continuous recording of element concentration (11,12). Studies already showed that there is a correlation between trace element concentration in hair and human diseases (13). In addition, studies have shown that, after prolonged exposure to certain trace elements, it creates an increased sensitivity to various diseases such as diabetes, cardiovascular diseases, cancer, and mutagenicity (14-16). An element can be caused by elements that accumulate in certain tissues for a long time until it reaches a critical level that causes disease in the body, or it can remain hidden for a long time between exposure and the first symptoms of the disease (17,18).

In this study, it is aimed to explain the relationship between the smoking status, domestic smoking and feeding regimes of the late adolescent period students of Sinop University, School of Health, and toxic and heavy metal levels in the hair.

Material and Methods

Participants

The population of the study consisted of 18-21 age (late adolescent period) group studying at the School of Health. As the case selection criterion for determining the sample of the study, students who accepted to participate in the study at this college, who did not have any mental or chronic disease/syndrome, and who did not use drugs continuously were selected. Necessary explanations were made to the students. Necessary verbal and written permissions were obtained.

Study Objectives

This study aimed to determine the effects of smoking status and dietary habits on heavy metal accumulation in late adolescent students studying at Sinop University.

Experimental Design

This experimental research was carried out between 09 October and 15 November 2019. Ethics Committee permission was obtained from Sinop University for the research numbered 2019/38. While the population of the study was composed of 18-21 age group studying at Sinop University School of Health, the sample was 41 students who volunteered to participate in the study according to the case selection criteria. For the collection of research data, an information form about the weekly consumption of foods and smoking status was prepared by the researchers considering the geographical and physical locations where the students are located. This information form is about the frequency of dietary questions including lettuce, salami, trout, instant soup, and chips. The forms were filled face to face with the students participating in the research. After collecting the forms filled by students, 0.5 g hair samples were collected from 41 students who volunteered to be analyzed for the concentration of heavy metal in their hair. In order not to affect the analysis result, care was taken not to have the hair dyed while collecting the hair sample. Hair samples taken, ultra high purity 3 mL HNO_3, and 9 mL HCl were added and dissolved in high pressure Teflon containers for half an hour at 200 °C. Samples were then transferred to 50 mL falcon tubes. The obtained filtrate was completed with 50 ml of ultrapure water and dissolved. In measuring the metal content from samples, it was measured with inductively-connected plasma mass spectrometry (ICP-MS) at Sinop University (ICP-MS) and reported as micrograms per kilogram (μg / kg).

Statistical analyses

The normality test of biochemical values obtained from the study performed with Shapiro Wilk tests. It was determined that the data didn't have normal distribution ($p < 0.05$). Mann-Whitney U test was used to compare heavy metal values (Al, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, Hg, and Pb) according to some demographic features and the type of food consumed. The values obtained as a result of the analysis are given in the tables as median (Q_1-Q_3). Analyzes were carried out in IBM SPSS 22.0 package program. $p < 0.05$ significance level was chosen.

Results

A total of 41 students participated in the study, and the mean ages of the students is 19.70±09.

Heavy metal values were compared according to the smoking status of the participants (Table 1). Accordingly, Fe value showed a statistically significant difference according to smoking status ($p < 0.05$). Me-

Table 1. Comparison of heavy metal values by participants' cigarette exposure

Variables	Smoking status		Smoking status of the family	
	Yes	No	Yes	No
Al	19876,80 (12817,84-29297,65)	21064,60 (15007,05-35485,93)	25022,69 (18490,00-38246,43)	17423,58 (11710,12-19826,62)
	p=1,000		p=0,005*	
Cr	327,37 (195,54-430,02)	318,68 (254,31-483,32)	327,37 (268,57-509,47)	285,92 (166,53-432,43)
	p=0,678		p=0,197	
Mn	1216,72 (593,48-1625,08)	1017,31 (746,44-2042,59)	1168,29 (770,52-2480,28)	833,67 (604,46-1517,34)
	p=0,758		p=0,248	
Fe	19802,86 (16725,04-23143,55)	26293,66 (23245,42-31396,78)	24907,81 (20257,78-31460,65)	22133,60 (17166,05-26440,54)
	p=0,003*		p=0,085	
Co	87,82 (66,07-366,83)	124,22 (65,64-299,86)	139,60 (77,39-348,14)	68,68 (63,44-237,58)
	p=0,841		p=0,154	
Ni	1249,04 (906,17-1834,31)	1831,55 (987,19-2797,27)	1684,95 (1120,82-3436,08)	1019,14 (843,31-2289,20)
	p=0,398		p=0,059	
Cu	26285,32 (19496,43-28869,97)	21917,09 (9719,70-29960,46)	26908,23 (20369,78-41891,65)	16118,21 (7580,74-24606,78)
	p=0,211		p=0,001*	
Zn	642887,30 (325944,30-944914,50)	919638,27 (432531,94-1668253,46)	642887,30 (467829,71-1158994,91)	798090,76 (356154,32-1697527,86)
	p=0,231		p=0,625	
As	120,27 (104,20-1365,91)	117,54 (106,41-171,40)	117,66 (104,17-169,62)	115,20 (105,06-169,09)
	p=0,925		p=0,802	
Cd	37,03 (33,22-65,16)	44,55 (35,57-61,52)	45,77 (38,85-67,53)	35,60 (30,58-46,86)
	p=0,301		p=0,010*	
Hg	63,04 (43,15-128,26)	90,14 (71,30-118,56)	98,33 (69,62-125,53)	68,88 (43,96-92,97)
	p=0,445		p=0,049*	
Pb	661,09 (355,84-941,23)	1026,06 (471,34-1431,83)	941,23 (590,00-1334,14)	542,31 (355,22-1297,95)
	p=0,211		p=0,147	

*p<0,05

dian Fe value is lower in smokers than non-smokers. Similarly, Al, Cu, Cd, and Hg values showed a statistically significant difference according to the status of smokers in the family. (P <0.05). Accordingly, the median values of Al, Cu, Cd, and Hg of the participants who have smokers in their family are higher.

Heavy metal values were compared according to the food type consumption of the participants (Table 2). Accordingly, Mn value showed a statistically significant difference according to lettuce consumption (p <0.05). Those who do not consume lettuce have a lower Mn value. Co value showed a statistically significant difference according to salami and processed food consumption (p <0.05). Those who do not consume salami and processed food have a lower Co value. Cu value showed a statistically significant difference according to the consumption of instant soup (p <0.05). Those who do not consume instant soup have a lower Cu value. Cd value showed a statistically difference according to trout consumption (p <0.05). Those who do not consume trout have lower Cd value. Pb value varies statistically significantly according to the consumption of chips (p <0.05). Those who do not consume chips have a lower Pb value.

Discussion and Conclusion

The term heavy metal is used as a side meaning in terms of pollution and toxicity with environmental pollution. Some of these elements are micronutrients for plants and animals (Fe, Cu, Zn, Mn, Mo, and Ni) and do not show toxic effects unless they exceed the permissible limit (19). Some heavy metals such as Zn, Fe, Cu, Mn are among the absolutely necessary metals, even in trace amounts for both the plant and the human body, and are also known as micronutrients (trace elements). However, high doses of these elements can create a poison effect on the body (20).

The fact that the essential elements obtained from the hair analysis are more or less, for example, Fe, and Zn element concentration deficiency also indicates that there may be serious problems in the physiological structure of the human (21, 22). It can also be used to investigate their exposure to chemical pollutants, such as toxic metals, including the effects of drug use

Table 2. Comparison of heavy metal values according to the consumption of different food types

Variables	Lettuce consumption		Processed food like salami		Package soup		Trout		Chips	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Al	22183,09 (15883,81-36984,32)	18505,35 (5995,48-25022,69)	18557,07 (11112,25-30524,40)	22226,56 (15113,70-36786,69)	21762,58 (17546,68-37637,25)	19670,82 (12177,44-28082,86)	29427,21 (17197,04-88940,35)	19876,80 (13752,47-29784,66)	23013,72 (15605,97-37883,96)	18608,79 (13227,29-29784,66)
	p=0,231		p=0,362		p=0,260		p=0,315		p=0,273	
Cr	336,58 (278,44-505,69)	258,17 (114,51-435,17)	333,07 (242,51-503,48)	319,53 (201,73-435,17)	305,87 (248,63-391,74)	337,28 (181,46-475,63)	444,86 (331,95-654,27)	317,84 (198,64-442,15)	318,68 (171,74-458,85)	327,37 (256,35-463,86)
	p=0,096		p=0,860		p=0,628		p=0,188		p=0,549	
Mn	1283,30 (746,44-2849,75)	826,61 (417,21-1238,91)	955,54 (549,41-2042,59)	1164,80 (717,98-1625,08)	1389,09 (919,13-1592,59)	836,60 (600,87-3095,98)	1345,32 (788,19-1551,53)	1022,97 (630,22-2057,10)	1150,97 (586,22-5038,70)	1011,64 (690,32-1449,76)
	p=0,046*		p=0,776		p=0,249		p=0,751		p=0,389	
Fe	23998,36 (19593,51-29955,39)	23972,87 (17015,69-31588,39)	24065,41 (19033,41-34694,85)	23848,78 (18965,47-29807,86)	26651,03 (21068,69-37165,71)	23674,06 (18464,88-27118,08)	26489,70 (25278,85-36147,07)	23499,34 (18727,28-29961,57)	25453,85 (22069,22-30852,27)	22336,12 (18711,14-26973,00)
	p=0,947		p=0,755		p=0,096		p=0,203		p=0,220	

Table 2. Comparison of heavy metal values according to the consumption of different food types

Variables	Lettuce consumption		Processed food like salami		Package soup		Trout		Chips	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Co	176,83 (82,83-354,18)	69,81 (23,63-98,11)	70,30 (53,36-200,19)	159,02 (73,76-436,36)	98,11 (63,61-572,10)	123,86 (67,62-237,83)	429,32 (141,58-612,14)	99,18 (65,13-233,32)	124,22 (63,97-330,78)	98,11 (68,19-339,35)
	p=0,005*		p=0,032*		p=0,967		p=0,111		p=0,754	
Ni	1571,70 (1031,31-3159,58)	1218,78 (873,94-1987,19)	1109,41 (824,69-2797,27)	1368,87 (1071,91-2550,15)	1978,15 (810,36-4246,75)	1343,74 (984,12-2173,60)	3245,30 (1047,42-4601,88)	1340,11 (950,79-2470,01)	1353,75 (944,02-3458,03)	1347,37 (950,49-2373,46)
	p=0,231		p=0,269		p=0,730		p=0,431		p=0,876	
Cu	24038,01 (18052,28-28266,75)	21134,65 (7655,22-41640,33)	20159,84 (12015,82-41356,92)	24794,08 (14157,12-29414,38)	27938,69 (20159,84-153502,57)	21557,64 (11572,35-27880,64)	39014,10 (23456,19-401240,91)	21872,15 (12452,46-29142,18)	22251,86 (10481,30-38300,43)	23281,93 (18025,26-28898,53)
	p=0,602		p=0,596		p=0,036*		p=0,067		p=0,676	
Zn	647077,16 (493585,67-1517932,77)	941484,79 (325944,30-1397516,51)	507042,66 (325761,20-1298223,49)	824750,38 (494112,19-1512103,21)	589395,99 (376978,06-1033695,08)	731263,62 (488709,83-1529591,88)	1076187,28 (862076,70-1553573,50)	589395,99 (376978,06-1423402,13)	943199,65 (489236,34-1496399,34)	589395,99 (376978,06-1267682,46)
	p=0,461		p=0,294		p=0,463		p=0,203		p=0,389	
As	116,06 (107,13-173,49)	123,66 (60,25-145,01)	118,84 (93,21-173,78)	117,66 (105,61-165,91)	112,30 (106,63-160,08)	118,97 (103,10-169,54)	140,81 (94,75-182,72)	117,66 (104,91-165,01)	122,10 (93,52-182,56)	114,70 (106,63-154,56)
	p=0,779		p=0,924		p=0,923		p=0,816		p=0,549	
Cd	45,41 (36,15-66,71)	37,03 (34,70-47,81)	35,03 (30,79-50,84)	46,26 (37,03-65,16)	45,77 (35,03-70,93)	40,32 (34,78-56,79)	75,97 (54,33-101,49)	39,74 (34,80-49,06)	46,26 (36,17-68,04)	38,48 (33,19-53,59)
	p=0,253		p=0,059		p=0,609		p=0,010*		p=0,159	
Hg	91,97 (61,42-110,76)	81,26 (49,81-127,19)	86,01 (46,13-147,25)	89,78 (56,55-111,56)	74,65 (49,24-120,61)	91,61 (58,27-119,53)	93,88 (64,77-100,93)	89,78 (52,13-123,03)	92,27 (75,04-115,90)	74,65 (43,03-129,49)
	p=0,799		p=0,946		p=0,463		p=0,983		p=0,335	
Pb	876,25 (408,56-1197,98)	784,44 (448,29-1404,93)	551,84 (325,65-1320,36)	941,23 (553,05-1395,28)	989,85 (465,79-2135,45)	816,95 (378,95-1243,82)	1195,69 (513,73-3234,38)	784,44 (437,21-1220,90)	1109,05 (711,19-1506,50)	553,05 (355,43-965,54)
	p=0,820		p=0,176		p=0,570		p=0,382		p=0,016*	

*p<0,05

(5). In addition to the toxic elements that can be taken from the smoke during smoking, passive smoking also plays an important role in the exposure of children to these toxic heavy metals (23). Inhalation of cadmium-containing tobacco smoke is a dominant source of cadmium exposure (24). Children are more sensitive to the effects of toxic elements such as Pb than adults (23). When the heavy metal status of the participants according to their smoking status was compared, the Fe value showed a statistically significant difference ($p < 0.05$) between smokers and non-smokers. Fe value median is lower in smokers than non-smokers. Similarly, Al, Cu, Cd, and Hg values showed a statistically significant difference ($p < 0.05$) in individuals who have a smoker in their family. Median values of Al, Cu, Cd, and Hg are higher in participants who have a smoker in their families (Table 1). Researches on this subject showed that the levels of Cu, Cd, and Pb elements (4, 25, 26) are significantly higher in the hair of smokers and due to the increase in the number of smokers in the home. It shows that Cd and Pb levels (26, 27) increased. Similarly, it is reported that there was a positive correlation between the frequency of smoking at home and Pb, Cd, Cu, Ni, and Sb levels, and this correlation between family members' smoking status and toxic trace element levels in the hair was more significant with Pb and Cd levels (28). In addition, when the relationship between the average element concentration ($\mu g.kg^{-1}$) in the hair of the students participating in the study and their smoking status was examined, it was found that Fe concentration was statistically significant ($p < 0.05$).

Environmental pollution, which can develop due to the transition of modern agriculture, industrialization and urbanization with the impact of the rapidly increasing population in the world (29), affects various food sources such as cereal products, meat, and milk of animals fed with grass contaminated with metals, aquatic organisms hunted from polluted waters and food chain. It can reach people and create important health problems (30-33). As a result of this research conducted at Sinop University, it has been revealed that there is a statistically significant relationship between some food groups (lettuce, chips, instant soup, salami, trout) that students express at least once a week and the heavy metal concentration detected in their hair. It has been reported by various researchers that the primary source of essential and toxic elements in food is soil and contains a wide range of varying concentrations of metal with the elements necessary for growing the plant (34-37). It has been revealed by various studies that the nutrients grown in metal-containing soils also increase their heavy metal content (38-42). However, it has been reported by some studies that some fertilizers and pesticides also contain high levels of toxic metals and this can lead to heavy metal contamination in foods (43-45).

In the current study, it was determined that there was a statistically significant between the students' preferences of eating lettuce ($p < 0.05$) in terms of Mn and Co concentration values and it was found that it was higher in students who ate lettuce in terms of average concentration value. However, another important metallic pollution factor in foods is wastewater originating from various industrial activities, sometimes being trace and sometimes heavy metal at high concentrations (46). In addition, researches reveal that sewage water wastes have high concentrations of various potential toxic elements, generally Cd, Cu, Fe, and Zn (47, 48). Indeed, it is reported a high level of Pb, Zn, Cr, and Ni accumulation in vegetables grown around the river where wastewater mixes (49). Therefore, people who feed on fish hunted from areas where wastewater and sewage are mixed can also reach heavy metals through the food chain (50-52). It has been determined that there is a statistically significant relationship between the students who stated that they consumed trout at least once a week and heavy metals in their hair in terms of Cd ($p < 0.05$) (Table 2). Meat products, offal, and seafood are high levels of cadmium sources (53). Cadmium can dissolve in water, and it can reach many fish products that can be consumed as food by fish, including molluscs and crustaceans (mussels, crabs, etc.) that live and feed at the bottom by sinking to the bottom of the spilled water source (54,55). Therefore, at least once a week obtained as a result of this research, trout consumption is considered as the reason for the significant difference in Cd concentration in the hair. Methyl mercury (MeHg), the most toxic form for humans, is found in contaminated fish and poses a high health risk with high fish consumption (56-58).

There can also be heavy metal transitions into foods from various tools and cooking containers used during cooking and storage of foods. In a study it was reported that 0.13-0.22 ppb nickel contaminated food from stainless steel containers after one hour of cooking (59). In another study, it has been reported that some type of stainless steel pans are transmitted with an acid content of more than 400 ppm of nickel (47). However, that was reported that nickel content in traditional and fast-food foods increased due to spice, dried fruit, whole grain, mushroom contaminated with Nickel, which is added to foods (60) and claimed that dishes cooked in copper pots contain twice as much copper as dishes cooked in aluminum or stainless steel pots (61). In addition, it has been reported that the Pb level in pyrene cabbage in tinned copper pans increased from 0.15 mg/kg to 0.79 mg/kg and the Cu level increased from 1.36 mg/kg to 2.07 mg/kg (62). Most of the aluminum taken with food can be through the aluminum container, canned food, and aluminum foil used in cooking with additives (63). In addition, some detergents used to clean the equipment can cause As, Pb, and Cd dissolution in stainless steel and cause contamination (64). It is also reported that heavy metal contamination may occur during the packaging process. One of the research showed that Pb is a high percentage above bread packages (65). Furthermore candy packs that children frequently consume contain high levels of lead, especially in yellow and green ones (66).

It was found that there was a significant difference ($p < 0.05$) between the students who stated that they consumed ready-made soup at least once a week and those who did not, in terms of the concentration of Cu element detected in their hair. This suggests that this is probably due to the use of a variety of tools, cookware and heavy metal contaminated foodstuffs (spices, etc.) used during the industrial processing of instant soup. However, foods such as offal, cookies, and whole grain products can contain high levels of Cu (67). In addition, the average Pb concentration in the hair of students who stated that they consumed chips at least once a week was higher than those who did not consume, and a statistically significant difference was found between them ($p < 0.05$). The reason for this situation suggests that it developed due to Pb contamination during the packaging of chips in the light of related literature.

With physical exercise, blood circulation and metabolic rate increase (68), and secondary metabolites and harmful waste products produced by the body can also be excreted through sweat and urine (69,70). Although knowledge about the accumulation and excretion mechanisms of toxic elements in the human body is still limited, it suggests that sweat may be a better test example to monitor the accumulation and removal of toxic elements in the body (69-72). With sweating, a large amount of harmful substances can be removed from the body in the form of inorganic salts (73). Another of the harmful substances that can adversely affect human health when it accumulates excessively is heavy metals and can be removed from the human body by sweating. Some studies have reported that excretion rates of arsenic, cadmium, lead, and mercury are excreted with more sweat than urinary excretion (74). Indeed it is seen that sweat and urinary excretion of the heavy metals (Cr, Cu, Zn, Cd, and Pb) that were excreted from the body after physical exercise were significantly higher than those that were excreted in the urine after strenuous exercise (72). They also reported that physical exercise has a significant effect on the balance of trace elements, and that sweating during physical exercise can effectively remove toxic heavy metals from the body and reduce heavy metal buildup in the body. As a result of the research, they stated that they should actively participate in physical exercise to increase the detoxification capacity of individuals and to reduce the damage caused by heavy metals to their bodies.

The positive lifestyle he will acquire in the late adolescent period (18-21 years old), where he tries to step into the world of adults by trying to develop a new identity independently from his family, independent of his family, affects his well-being in the future. The development of risky behaviors such as smoking in this period causes the individual to adopt and maintain this behavior during adulthood as well (75). In addition, it is important to develop proper nutrition at this age. Fast-food eating or junk-eating habits are frequently encountered at this age. However, the proper eating habits acquired at these ages prevent the diseases that may be encountered in the future by forming a basis for the health of the individual in adulthood (76). Again at this age, sports form a very important basis for creating a healthy lifestyle. Regular sports activities that adolescents will start doing at this age affect bone, muscle, and adipose tissue and protect it from diseases such as osteoprosis, obesity, and respiratory system in the future (77). Health education to be provided by the nurse in preventive diseases is very important at this point (78). This research revealed the risks of heavy metal coming from various sources based on the answers given to the questionnaire questions of late adolescent students studying at Sinop University and the results of the heavy metal analysis in their hair. As a result of the study, it was determined that the students' smoking habits, their families were exposed to second or third-hand smoke due to smokers, and also the heavy metal element concentration in their hair varied due to differences in eating habits. In addition, it has been revealed in this research that regular consumption of foods containing different amounts of heavy metal can lead to heavy metal accumulation in the body. However, it has also shown that long-term consumption of foods contaminated with heavy metals due to various sources can also lead to accumulation in the body. Therefore, both nutritional habits and lifestyles of individuals are among the most controlling factors on heavy metal accumulation in the body. As a result, the individual encounters heavy metals in the late adolescent period. To prevent this, determining a healthy lifestyle, adding nutrition and regular sports into this style, staying away from risky behaviors such as smoking may contribute positively to his/her future life.

Conflict of interest statement

The authors declare that they have no conflict of interest.

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